Modeling the Effect of Internal Waves on Long-Range Propagation

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LONG-TERM GOALS

This project aims to understand the fluctuations in low frequency (100 Hz, for example) acoustical propagation in the ocean over long distances (50 km to thousands of km.), as well as other effects of internal waves and other small-scale variability in the speed of sound.

OBJECTIVES

The objective is to model results of recent low-frequency, deep-water acoustic-propagation experiments, constraining the model environment from the measurements of those environments. Phenomena such as intensity fluctuations and deep arrivals are of more concern than travel time fluctuations, as the physics of travel time fluctuations is much better understood.

APPROACH

This project has concetrated mostly on the analysis of environmental data to separate the physical processes leading to sound speed fluctuations, and then to use semi-empirical models of these processes for acoustic propagation calculations. Small-scale internal waves and "spice" are the processes of concern for predictions of fluctuations of intensity and spatial correlations and of the deep arrivals. CTD (conductivity, temperature, depth as measured by pressure) profiles are used to extract the small-scale internal waves and "spice". PE (“parabolic” equation) calculations have been used up until now to simulate the acoustics, but mode equation techniques are superior for some purposes.

WORK COMPLETED

Small-scale internal waves and spice fluctuations have been extracted from CTD profiles in three experiments, LOAPEX (a component of a 2004 long-range propagation experiment), and two Philippine Sea experiments of 2009 and 2010. The vertical wavelength spectra of these results have been evaluated. Acoustic simulations of intensity fluctuations for the 2009 experiment have been done.

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RESULTS

In all cases, the internal wave results are consistent with a modified Garrett-Munk model. Enough is known about internal waves so that we can have some confidence that such a model is a good description of the internal wave field. The strength of the internal wave field relative to the Garrett-Munk average value varied from 0.5 at LOAPEX to about 1.4 in the Philippine Sea. The spice contribution is large in LOAPEX and in the 2010 Philippine Sea experiment, but is small in the 2009 experiment and in that part of the 2010 experiment located close to the positions of the 2009 CTD profiles.

The vertical spectra of internal wave and spice strains are shown in the figures. Although spectra of spice are shown, a spectral model is not an adequate model. The spice fluctuations are highly intermittent, instead of being close to a Gaussian process. Moreover, the horizontal structure of spice and its relationship to the measured vertical structure are unknown. These features are expected to be important to acoustic propagation. A towed CTD chain that was deployed was intended to measure these features, but the data seem to be inadequate to resolve the strucure of the spice.

West of longitude 127° E, The amount of spice fluctuations is rasther small. For acoustic propagation limited to that region (in both 2009 and 2010), an internal wave model of the usual type is reasonably correct. However, west of that longitude in 2010, such a model is not likely to correctly predict the acoustics.

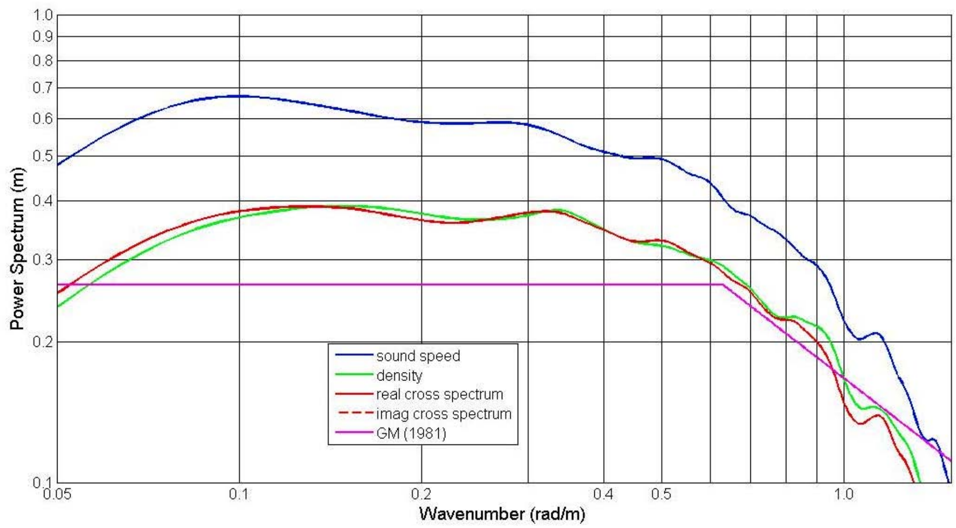

Figure 1 The average strain spectra for the 2010 Philippine Sea experiment. The spectrum defined from density only contains internal waves, it has the same shape as the Garrett-Munk spectrum, and it is smaller than that defined from sound speed, which contains both internal waves and spice. The cross spectrum agrees with the density defined spectrum, validating the method. The imaginary part of the cross spectrum is tiny, and lies below the bottom of the graph. The spice spectrum, which is the difference, is not small compared to the internal wave spectrum.

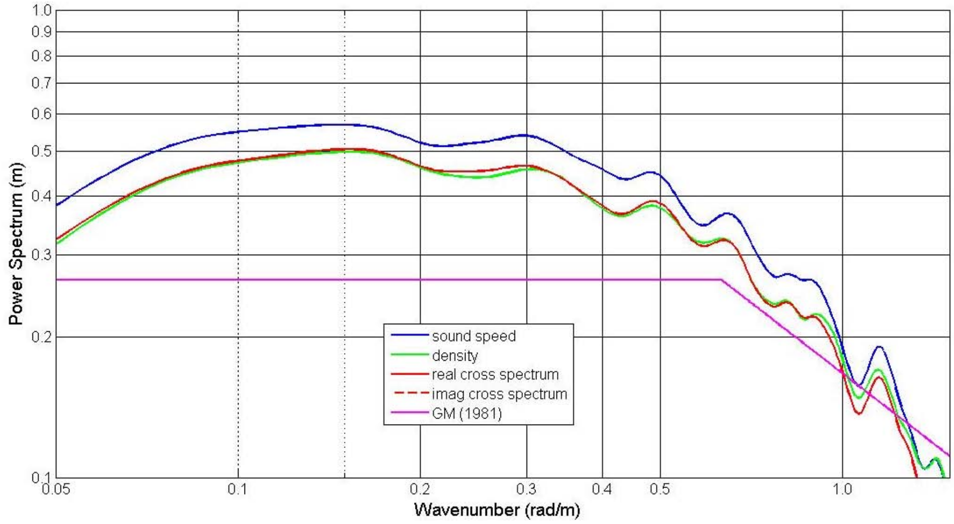

Figure 2 The same as figure 1, but the data are restricted to those taken west of longitude 127° E. For these data, the spice contribution is much less significant than in the totality of the data.

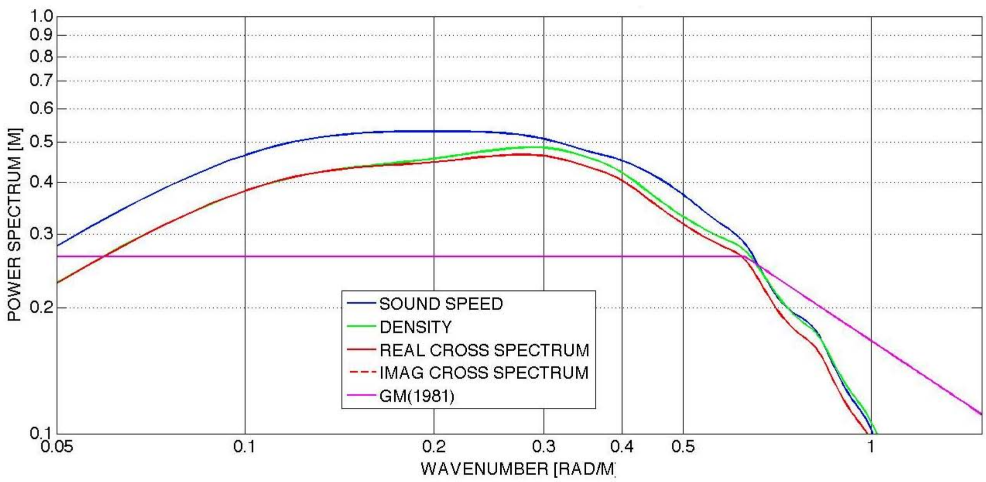

Figure 3 The average spectra frrom the 2009 experiment, for which all profiles were west of 127° E. The results are very similar to those in 2010, restricted to be west of 127° E.

IMPACT/APPLICATIONS

Good propagation calculations are important for sonar performance predictions and design. The small-scale sound speed fluctuations used in propagation calculations are modeled as internal waves. For better predictions, the different properties of the spice fluctuations must be included.

RELATED PROJECTS

The main Applied Physics Lab low-frequency, long-range propagation project (Jim Mercer, PI) is closely coordinated with this project.